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An Overview on Production, Properties, Performance and Emission Analysis of blends of Biodiesel

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Abstract

The steep rise of demand of petroleum based fuel is because of rapid and fast industrialization of automotive sector. There are limited reserves for petroleum based fuels. These limited reserves are located in the certain regions of the world. Therefore the countries those are not having the sufficient stock of petroleum based fuel, are facing the problems of increase cost of fuel which mainly due to the cost involved in the import of the petroleum based fuel. Hence it is required to find out and investigate the other resources of the alternative fuels, which can be produced from nearby and locally available sources such as Alcohol, Biodiesel, Vegetable oil etc. Methyl or ethyl esters of fatty acids produced from vegetable oil or an animal fat is called biodiesel. Non edible oil or animal fats are the main recourses for production of biodiesel such as Jatropha, Palm, Marine fish oil, Soybean, Cottonseed etc. Biodiesel blends are prepared in any proportion with diesel to use in a conventional diesel engine. By using biodiesel in an engine there is a significant reduction in the harmful pollutants in the environment. This paper reviews the production, properties, performance and emission analysis of different feedstock of blends of biodiesel and experimental work carried out in the various parts of the world.

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Keywords: Biodiesel, Blends of Biodiesel, Production, Properties, Emission, Performance

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Nomenclature

FAAE	Fatty Acid Alkyl Ester
FAME	Fatty Acid Methyl Ester
CP	Cloud Point
PP	Pour Point
CFPP	Cold Filter Plugging Point
CI	Compression Ignition

1. Introduction

Biodiesel is a biodegradable and non toxic fuel produced from vegetable oil and animal fats which are renewable. It can be used in C.I (Compression Ignition) engine without modification. The biodiesel combustion by products are better not only for inhabitants but also for earth's environment. The emissions of unburned hydrocarbon, carbon monoxide, particulate matter of biodiesel combustion are much lesser than conventional diesel fuel. As biodiesel is produced from natural sources it contains very few amount of sulfur which leads to less emissions of sulfur dioxide when it burns in an engine. Generally the blend of biodiesel diesel mix is denoted by alphabet "B" followed by percentage of biodiesel in a mixture ; so if 20% biodiesel and 80% diesel is in a mixture on a volume basis then it is denoted as B20.Biodiesel tends to freeze or crystallize in cold weather conditions and may be unsuitable to use in an engine. In order to criticize biodiesel as an alternative fuel, people used this point. But there are many techniques by which one can use biodiesel even in cold weather conditions. Biodiesel is safer in handling and in storing as a fuel, because its flash point is more than petroleum based fuel. The cost of various feedstock of biodiesel is different as per availability and as per production technology. As the demand will increase the cost of biodiesel will also decrease. One of the major reasons to have favourable conditions to use biodiesel as alternative fuel, is the cost of crude oil which is very high and varying on daily basis. This leads to a growing awareness in the field of biodiesel in developed and in developing countries.

1.1 Chemistry of Vegetable oil and Animal fats

The structure of vegetable oil varies from straight chain to complex structure of proteins and fat soluble vitamins. Fats and oil are water insoluble, hydrophobic substances in the animal and plant kingdom which are made up of three mole of fatty acid and one mole of glycerol which is commonly called as triglycerides. Generally vegetable oil found to be structure of triglycerides with a number of branched chains with different varying length. But fatty acid varies in length of carbon chain and in unsaturated double bond. Commonly fatty acid chain structures are given in Table 1 and compositions of common fatty acids for vegetable oils are given in Table 2.

Table 1. Chemical Structures of common fatty acids [53]

Fatty Acid	Systematic Name	Structure	Formula
Lauric	Dodecanoic	12:0	$C_{12}H_{24}O_2$
Myristic	Tetradecanoic	14:0	$C_{14}H_{28}O_2$
Palmitic	Hexadecanoic	16:0	$C_{16}H_{32}O_2$
Stearic	Octadecanoic	18:0	$C_{18}H_{36}O_2$
Arachidic	Eicosanoic	20:0	$C_{20}H_{40}O_2$
Behenic	Docosanoic	22:0	$C_{22}H_{44}O_2$

Lignoceric	Tetracosanoic	24:0	$C_{24}H_{48}O_2$
Oleic	cis-9- Octadecanoic	18:1	$C_{18}H_{34}O_2$
Linoleic	cis-9,cis-12-Octadecadienoic	18:2	$C_{18}H_{32}O_2$
Linolenic	cis-9,cis-12 cis-15-Octadecatrienoic	18:3	$C_{18}H_{30}O_2$
Erucic	cis-13-Docosenoic	22:1	$C_{22}H_{42}O_2$

Table 2 .Compositions of common fatty acids for vegetable oils [54]

Vegetable Oil	Fatty acid composition (wt %)									
	14:0	**16:0**	**18:0**	**20:0**	**22:0**	**24:0**	**18:1**	**22:1**	**18:2**	**18:3**
Corn	0	12	2	Tr	0	0	25	0	6	Tr
Cottonseed	0	28	1	0	0	0	13	0	58	0
Crambe	0	2	1	2	1	1	19	59	9	7
Linseed	0	5	2	0	0	0	20	0	18	55
Peanut	0	11	2	1	2	1	48	0	32	1
Rapeseed	0	3	1	0	0	0	64	0	22	8
Safflower	0	9	2	0	0	0	12	0	78	0
H.O.Safflower	Tr	5	2	Tr	0	0	79	0	13	0
Sesame	0	13	4	0	0	0	53	0	30	6
Soyabean	0	12	3	0	0	0	23	0	55	0
Sunflower	0	6	3	0	0	0	17	0	74	0
Rice-bran	0.4-0.6	11.7-16.5	1.7-2.5	0.4-0.6	-	0.4-0.9	39.2-43.7	-	26.4-35.1	-
Sal	-	4.5-8.6	34.2-44.8	6.3-12.2	-	-	34.2-44.8	-	2.7	-
Mahua	-	16.0-28.2	20.0-25.1	0.0-3.3	-	-	41.0-51.0	-	8.9-13.7	-
Neem	0.2-0.26	13.6-16.2	14.4-24.1	0.8-3.4	-	-	49.1-61.9	-	2.3-15.8	-
Karanja	-	3.7-7.9	2.4-8.9	-	-	1.1-3.5	44.5-71.3	-	10.8-18.3	-

Tr=Traces

As compared to diesel oil, vegetable oil has 10-12% less heating value due to the presence of oxygen. Because of complex structure and large molecular weight the viscosity of vegetable oil is more than conventional diesel fuel. High viscosity of vegetable oil causes serious problems in pumping of fuel and poor atomization of fuel through a fuel injector. Similarly high flash point of vegetable oil contributes to lower volatility characteristics which lead to improper and incomplete combustion, carbon deposition, piston ring wear, lubricating oil wear and dilution. Poor cold weather condition starting problem, ignition delay and misfire are the few outcomes of combination of high viscosity and low heating value of vegetable oils. Because of all such type of problems vegetable oils must be modified chemically in to the suitable fuel to an engine.

1.2 Transesterification

Vegetable oil is converted in the biodiesel by using transesterification process. In the transesterification process the oil is directly react with alcohol and forms esters and glycerol. Propanol amyl alcohols are also used in the process to increase rate of reaction. Generally Alkali catalyzed transestrification is used than acid transestrification because of its faster rate of reaction[32,33]. The viscosity of vegetable oil changes drastically because of transestrification process. But mostly transestrification process is affected by reaction time, temperature, molar ratio and moisture.

2. Production of Biodiesel

Many scientists and researchers had developed very different methodologies for the production of biodiesel from different feed stocks of vegetable oil and animal fats. D.H.Qi et al.[14] produced Biodiesel from transestrification process of soybean oil, with methanol (CH_3OH) catalyzed by potassium hydroxide (KOH). P.K. Sahoo et al. [16] studied non-edible filtered Jatropha (Jatropha curcas), Karanja (Pongamia pinnata) and Polanga (Calophyllum inophyllum) oil based mono esters (biodiesel) produced and blended with diesel were tested for their use as substitute fuels of diesel engines. Mata T.M [26] studied the viability of producing biodiesel from three types of waste animal fats (tallow, lard, and poultry fat). Avinash Kumar Agarwal [1] in his paper reviewed the production, characterization and current status of vegetable oil and biodiesel.

Zafer Utlu [12] in his study used methyl ester obtained from waste frying oil (WFO) was examined as an experimental material. A reactor was designed and installed for production of methyl ester and determined its physical and chemical properties. Ahn . [27] followed a two-step reaction process to produce biodiesel. Using this method canola methyl ester (CME), rapeseed methyl ester (RME), linseed methyl ester (LME), beef tallow ester (BTE) and sunflower methyl ester (SME), synthesized in a batch reactor using sodium hydroxide, potassium hydroxide and sodium methoxide as catalysts. Kusdiana et al .[28] discussed the effects of water on biodiesel fuel production by supercritical methanol treatment. Ramadhas [17] studied biodiesel production from high free fatty acid rubber seed oil. They developed a two-step transesterification process to convert the high free fatty acid oils to its mono-esters. Waste frying oils transesterification was studied by Felizardo.[29] with the purpose of achieving the best conditions for biodiesel production. A. Wisniewski Jr.[5] in his paper reported that, waste fish oil was converted into bio-oil by a fast pyrolysis process at 525 ^{0}C in a continuous pilot plant reactor with 72–73% yield.The bio-oil was distilled to obtain light bio-oil and heavy bio-oil and these biofuels were characterized in terms of their physico-chemical properties.

Sharanappa Godiganur et al. [3] stated that, the high viscosity of fish oil leads to problem in pumping and spray characteristics. The inefficient mixing of fish oil with air leads to incomplete combustion. The best way to use fish oil as fuel in compression ignition (CI) engines is to convert it into biodiesel. Cherng-Yuan Lin et al.[4] studied fuel properties of biodiesel produced from the crude fish oil from the soapstock of marine fish. The soapstock of a mixture of marine fish was used as the raw material to produce the biodiesel. The soapstock was collected from discarded fish products. The refined fish oil was transesterified to produce biodiesel. The fuel properties of the biodiesel were analyzed. L. Zhu et al.[34] considered Algae as a promising biodiesel feedstock. An integrated approach was investigated combining freshwater microalgae Chlorella zofingiensis wintering cultivation in pilot-scale photo bioreactors with artificial wastewater treatment. The study was emphasized on design of Mixotrophic culture with the addition of acetic acid (pH-regulation group) and autotrophic culture . The lipid and biodiesel production, characteristics of algal growth, and nitrogen and phosphate removal were examined. X.Yin et al.[35] studied production of biodiesel from soybean oil deodorizer distillate which was enhanced by counter-current pulsed ultrasound and also reported the compared results of counter-current probe ultrasonic enhanced transesterification (CCPUE) over static probe ultrasonic enhanced transesterification (SPUE) on the biodiesel conversion technologies.

S. Yang et al.[36] investigated a new non-food feedstock, i.e grease which was derived from swine manure-grown housefly larvae. Approximately 21.6% of crude grease was extracted from housefly (Musca domestica L.) larvae reared on swine manure. The extracted grease was evaluated for biodiesel production concerning the variables affecting the yield of acid-catalyzed production of methyl esters and the properties of the housefly larvae-based biodiesel. R. Wang et al.[37] For the first time Stauntonia chinensis (SC) seed oil obtained from processing waste was reported and investigated as a feasible biodiesel feedstock. E. Uçkun Kiran et al.[38] investigated that one third of food produced for human consumption is wasted in food supply chain. In several countries food waste is utilized for landfills. However these food waste can be considered as one of the source for the biofuel with the advanced conversion technologies R. Tripathi et al.[39] studied a Microbacterium sp. as a good source for the production of lipase enzyme used in transesterification reaction for biodiesel production. P.

Thliveros et al.[40] investigated a new method in the production of biodiesel that used direct base-catalyzed methanolysis of the cellular biomass of oleaginous yeast Rhodosporidium toruloides Y4. Catalyst NaOH was used for transesterification process. S. H. Teo et al.[41] studied non-edible jatropha curcus oil (JCO) as a possible feedstock for the production of biodiesel. Calcium-based, CaO–Nd2O3 (calcium neodymium) and CaO–NiO (calcium nickel) mixed oxides, were synthesized via co-precipitation process. M. Tang et al.[42] reported that Pistacia chinensis Bunge as one of ideal species for producing biodiesel. D. Surendhiran et al.[43] developed a non-alcoholic route in a solvent free system of production of biodiesel from microalgae. N. Shibasaki-Kitakawa et al.[44] studied and reported that waste acid oil as a feasible feedstock for the production of biodiesel which also satisfied the international specification of biodiesel.

3. Properties of Biodiesel

The properties of biodiesel are very close and similar to the conventional fuels; therefore biodiesel becomes a very good and low cost alternative to the diesel fuel. Transesterification process converts the triglycerides in to methyl and ethyl esters, which reduces the molecular weight to one third of the triglycerides, viscosity by factor about eight and slightly increases the volatility [1]. Biodiesel contains 10-12% more oxygen by weight, which accelerate the rate of combustion in an engine. Approximately the cetane number of biodiesel is around 50. Biodiesel also has a high flash point but lower heating value than the conventional diesel. Various physical and thermal properties of vegetable are shown in table 3 and table 4 shows the various properties of biodiesel prepared from vegetable oil.

Table 3 Physical and thermal properties of vegetable oils [1]

Vegetable oil	Kinematic Viscosity at 40^0C	Cetane no.	Heating value (MJ/kg)	CP (^0C)	PP (^0C)	Flash point (^0C)	Density (kg/l)	Carbon residue (wt%)	Ash (wt%)	Sulfur (wt%)
Corn	34.9	37.60	39.50	-1.1	-40.0	277	0.9095	0.24	0.010	0.01
Cottonseed	33.5	41.8	39.5	1.7	-15.0	234	0.9148	0.24	0.010	0.01
Cramble	53.6	44.6	40.5	10.0	-12.2	274	0.9044	0.23	0.050	0.01
Linseed	22.2	34.6	39.3	1.7	-15.0	241	0.9236	0.22	<0.01	0.01
Peanut	39.6	41.8	49.8	12.8	-6.7	271	0.9026	0.24	0.005	0.01
Rapeseed	37.0	37.6	39.7	-3.9	-31.7	246	0.9115	0.30	0.054	0.01
Safflower	31.3	41.3	39.5	18.3	-6.7	260	0.9144	0.25	0.006	0.01
H.O.Saffower	41.2	49.1	39.5	-12.2	-20.6	293	0.9021	0.24	<0.001	0.02
Sesame	35.5	40.2	39.3	-3.9	-9.4	260	0.9133	0.25	<0.01	0.01
Soybean	32.6	37.9	39.6	-3.9	-12.2	254	0.9138	0.27	<0.01	0.01
Sunflower	33.9	37.1	39.6	7.2	-15.0	274	0.9161	0.23	<0.01	0.01
Palm	39.6	42.0	-	31.0	-	267	0.9180	-	-	-

Babassu	30.3	38.0	-	20.0	-	150	0.9460	-	-	-
Tallow	-	-	40.0	-	-	201	-	6.21	-	-

Table 4 Properties of biodiesel prepared from vegetable oil [1]

Properties	**Biodiesel**					
	Peanut	**Soybean**	**Palm**	**Sunflower**	**Linseed**	**Tallow**
Kinematic Viscosity at 37.8 ^{0}C	4.9	4.5	5.7	4.6	3.59[a]	-
Cetane Number	54	45	62	49	52	-
Lower heating Value (MJ/l)	33.6	33.5	33.5	33.5	35.3	-
Cloud Point	5	1	13	1	-	12
Pour Point	-	-7	-	-	-15	9
Flash Point	176	178	164	183	172	96
Density (g/ml)	0.883	0.885	0.88	0.86	0.874	-
Carbon residue (wt %)	-	1.74	-	-	1.83	-

[a] At 40^{0}C

Different properties of biodiesel were studied in the various parts of the world. A comprehensive review is presented in order to study the experimental methodology for understanding the various properties of biodiesel. Pedro Benjumea [20] studied the basic properties of palm oil biodiesel–diesel blends. Murugesan [6] reviewed biodiesel as an alternative fuel for diesel engines. Ertan Alptekin et al.[30] studied commercially available two different diesel fuels which were blended with the biodiesels produced from six different vegetable oils (sunflower, canola, soybean, cottonseed, corn oils and waste palm oil). The blends (B2, B5, B10, B20, B50 and B75) were prepared on a volume basis. The key fuel properties such as density and viscosities of the blends were measured by ASTM test methods.

S. Bajpai et al.[45] used methanol, ethanol, propanol and butanol for formation of alkyl esters of Jatropha, Karanja and Castor and optimized alcoholysis process for preparing alkyl esters of Jatropha, Karanja and Castor oil and reported that lower blends of ethyl, propyl and butyl esters of Jatropha and Karanja feedstock had similar properties to methyl esters but at higher blending ratio there was a deviation in the properties. A. B. Fadhil et al.[46] conducted an experiment on purification of biodiesel using activated carbon produced from spent tea waste. The study concluded and reported that the use of activated carbons for the purification of biodiesel improved the fuel properties, compared to those which were purified by using silica gel and water washing method.

M. H. M. Yasin et al.[47] studied fuel physical characteristics of biodiesel blends with alcohol as additives. They reported that density and viscosity of biodiesel blended with mineral diesel was reduced because of presence of alcohol in the concentration of blends. But there was a significant increase in cetane number as alcohol concentration starts too increased. The properties of newly developed biodiesel were meeting the requirement of EN14214. Table5 shows the various properties of biodiesel blended with mineral diesel and with alcohol.

Table 5 Properties of blends of biodiesel blended with mineral diesel and alcohol [47]

Properties	**Diesel**	**B20**	**B20 E5**	**B20 E10**	**B20 M5**	**B20 M10**	**B100**
Flash point (°C)	70	110	43	48	45	49	180
Viscosity (mm^2/s)	4.24	4.51	3.14	3.09	3.28	3.63	5.68
Density (kg/m^3)	837	845	843	842	844	843	878
Acid Value, mgKOH/g	0.24	0.2	0.54	0.52	0.59	0.78	0.3
Cetane number	71.6	78.2	92.7	88.6	92.4	91.2	98

S. S. M. Mostafa et al [48]. studied the feasibility of biodiesel produced from microalga Spirulina platensis according to the standard methods of analysis (ASTM) and compared to Egyptian petro-diesel. The obtained results reported that with the increase of biodiesel concentration in the blends; the viscosity, density, total acid number, initial boiling point, calorific value, flash point, cetane number and diesel index increase. While the pour point, cloud point, carbon residue and sulfur, ash and water contents decrease. The observed properties of the blends were within the recommended petro-diesel standard specifications and they were in favor of better engine performance.

A. M. Ashraful et al. [49] reviewed the various properties of non-edible biodiesels. S. H. Yoon et al.[50] performed experimental investigation to find out the fuel properties of soybean biodiesel such as specific gravity, density, and viscosity of diesel and soybean biodiesel fuel in the temperature range from 0 to 200 °C. Paper reported that, the specific gravity of biodiesel fuel increased with the increase of the blending ratio of biodiesel and gradually decreased as the fuel temperature increased linearly. Also the density values are correlated as a function of blend ratio and temperature.E. F. S. M. F. S. M. Ramalho et.al.[51] used a poultry feedstock for production of biodiesel and studied the thermo-physical properties of biodiesel at low temperature. Modulated Temperature Differential Scanning Calorimetry (MT-DSC) was used to understand the physical meaning of properties as Cold Filter Plugging Point (CFPP), Pour Point (PP) and Cloud Point (CP) of biodiesel.

R. M. Joshi et al.[52] studied the various flow properties of blends of biodiesel and reported that the dynamic viscosity of biodiesel and its blends increases as temperature decreases and show Newtonian behaviour down to the pour point. Dynamic viscosity, cloud point and pour point decreases with an increase in concentration of diesel in the blend.

4. Engine Performance

The performance parameters such as power output, specific fuel consumption, brake thermal efficiency of different biodiesels has been reviewed as follows,

Cherng-Yuan Lin et al. [2] studied engine performance and emission characteristics of marine fish-oil biodiesel produced from the discarded parts of marine fish. They reported that an increase in engine speed causes an increase in exhaust gas temperature, brake fuel conversion efficiency, and the equivalence ratio and a decrease in black smoke opacity, and the emission of NOx, CO, and O_2.

Sharanappa Godiganur et al. [3] studied performance and emission characteristics of a Kirloskar HA394 diesel engine operated on fish oil methyl esters. They found that, fish biodiesel as a effective alternative fuel for diesel fuel. Brake specific fuel consumption for B100 is higher than the diesel fuel and it is decreased in blended fuels. The maximum thermal efficiency for B20 (31.74%) was higher than that of diesel. The exhaust temperature increased as a function of the concentration of biodiesel blend .Increase in the exhaust temperature of a biodiesel-fuelled engine led to increase in NOx emissions for B100. This is due to the higher temperatures and presence of oxygen molecules present in biodiesel. The reduction in CO and HC was linear with the addition of biodiesel for the blends teste.

Murugesan et al.[6] reviewed bio-diesel as an alternative fuel for diesel engines. They reported that Methyl ester of bio-diesel (B100) can be directly used in diesel engines without any modifications for short term with slightly inferior performance than that of diesel. Brake thermal efficiency for bio-diesel is slightly increased in B20. Brake-specific energy consumption for B20 is reduced slightly. The CO, CO2, HC PAH emissions are reduced. NOx emissions are slightly increased it should be reduced by dual fuel mode. Addition of small quantities of bio-diesel to mineral diesel is a suitable strategy for increasing alternative fuel consumption, at least in agricultural engine

J.M. Luja´n [8] studied comparative analysis of a DI diesel engine fuelled with biodiesel blends during the European MVEG-A cycle performance and emissions (II).The study reported that biodiesel can be used safely in the diesel engine, at least in small blending ratios with normal diesel fuel. The fuel consumption increases as the biodiesel content in the fuel rises due to its lower heating power. Nevertheless, it should be noted that the biodiesel maintains the same engine efficiency at that obtained with diesel fuel. Increasing the biodiesel content reduces the particulates in the engine exhaust prior to the after-treatment.

Mustafa Canakci et al. [18] Predicted on performance and exhaust emissions of a diesel engine fueled with biodiesel produced from waste frying palm oil . They reported that the performance and exhaust emissions values of a diesel engine fueled with the waste frying oil biodiesel and its blends and modeled (predicted) for different engine speeds at full load condition

A.P. Roskilly et al.[10] describes the performance and the gaseous emissions of two small marine craft diesel engines fuelled with biodiesel. The test results show that the engine and boat performances when fuelled with biodiesel were comparable to that when fuelled with fossil diesel. The fuel consumptions while fuelled with biodiesel were higher than that while fuelled with fossil diesel, since a little more biodiesel must be supplied to the engines to produce an equivalent amount of work, NOx emission levels from both engines when fuelled with biodiesel were generally lower compared to that when fuelled with fossil diesel. Magı´n Lapuerta [11] analyses the effect of biodiesel fuels on diesel engine emissions.

Zafer Utlu et al. [12] investigated engine performance and emission with biodiesel fuel obtained from waste frying oil on direct injection diesel engine. They reported that , Waste frying oil methyl ester is a renewable energy resource. Diesel fuel and WFOME were similar in their chemical and physical properties. Since WFOME has a lower heating value, higher density and viscosity, WFOME's specific fuel consumption was increased as 14.34%. Emission values were decreased as 17.14% CO, 1.45% NOx. Smoke intensity was increased in average 22.46% for the utilization of WFOME compared to diesel fuel. Exhaust temperatures of WFOME was decreased on average 6.5% than diesel fuel. Waste frying oil methyl ester can be used cheaply and as an alternative fuel in a diesel engine instead of diesel fuel.

5. Conclusion

Biodiesel received much more attention because of its environmental benefits and economic as well as its availability in the form of natural resources. Biodiesel produced from non edible oil natural resources can distinguish the use of edible oil for the production of biodiesel. This increases its natural demand in the market of transportation sector and scientists and researchers are now studying possible new sources of non edible oil of plant based or animal fats. The review presented here concludes that the various feedstock of non edible plant based and animal fat based oil converted in to biodiesel can be utilized and can be considered as the one of the important source and alternative for diesel fuels.

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